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Sampling Fleeces for Determining Average Wool Fineness

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INTRODUCTION

Determination of the fineness of a fleece of wool has usually been based on samples taken from the sheep at the shoulder, side, and thigh. In some instances only one sample was measured, and this was from either the shoulder or side.

In 1930 Roberts (*4*) recognized that even some well-grown fleeces varied in diameter of fiber, and that a larger number of samples than was customarily taken was necessary for satisfactorily determining the fineness of a fleece. He proposed a method whereby the area from which a sample of wool was sheared from the body was divided into 32 zones, the wool from each of these subsamples to weigh not less than 2 gm. The number of individual fiber measurements required per subsample ranged from 1,500 to 9,000, which would include most wools—from very fine, uniform Merino to coarse, very uneven Lincoln wool. Although Roberts anticipated the use of this method to sample whole fleeces, he did not state how many samples would be required. Assuming that a sample should be taken from at least 3 body areas because of the differences in the character of the wool in each, the numbers of zones and fibers to be measured would be 3 times those given above.

Bosman and Van Wyk (*1*) state that at least 250 fibers should be measured to determine the fineness of the wool in a single body area. However, these investigators also fail to give the minimum number of samples necessary for satisfactory results. Furthermore, neither Roberts nor Bosman and Van Wyk give the exact routine for obtaining a representative sample of the whole fleece. Observations by the present authors substantiate the findings of these investigators that fleeces vary widely in fineness not only in different areas on the animal but also in different locations within the same

area. Differences in fineness along the length of staple from a fine Rambouillet fleece are known to be as great as differences between small areas of the body.

To obtain a representative sample, therefore, the logical procedure would be thoroughly to mix the fibers from a whole fleece or from selected portions from certain areas of the fleece. Since carding is used commercially to mix wool fibers, a study was made to determine the reliability of this method. The work was done in 1941 and 1942 at the United States Department of Agriculture, Beltsville Research Center, Beltsville, Md.

EXPERIMENTAL PROCEDURES AND MATERIALS

The study involved hand and machine carding. Two small hand cards were made from wire clothing similar to that used on the rolls of a carding machine by attaching the clothing to small wood blocks 2¼ by 3½ inches in size. Machine carding was done on a small machine known as a sample card.

For comparative purposes, average fiber-diameter measurements were made with the use of the device and technique described by Hardy (*2*), and the resulting cross sections were analyzed by the count method proposed by Hardy and Wolf (*3*). By using the cross-section method, tangling of the fibers in no way hindered the analysis. A single observation by the count method requires that approximately 100 wool fibers be viewed cross sectionally.

Two types of investigations were made: Preliminary work, involving only wool tops; and the main experimental work, which included the wool of the fleeces of Rambouillet wethers. In the latter, half unskirted fleeces were opened and dusted by passing them through a small cone duster of the type described by Wilson (*7*). They were then scoured before being sampled.

Wool Tops

Mixtures of wool tops were produced by both hand and machine carding. Tops were selected as they furnished the most uniform and highly refined materials obtainable. Measured by the cross-section method, the mean diameters of the various grades of tops studied were as follows:

	Microns		*Microns*
80's	18. 28	58's	25. 95
64's	20. 34	56's	27. 61
60's	21. 36	50's	27. 85

Carded blends of wool tops were made by combining 80's with 64's, 80's with 60's, 80's with 56's, 80's with 50's, 64's with 60's, 64's with 58's, 64's with 56's, 60's with 58's, 60's with 56's, 58's with 56's, and 58's with 50's. This series offered an opportunity of testing the mixing possibilities through carding of wools differing greatly in fineness, length, and crimp.

Of the two grades of wool used in each combination, equal portions were mixed by means of the two small hand cards. Each portion was made to weigh 0.300 $\pm$ 0.005 gm. In order to recognize the point where intimate fiber mixing occurs, one of the components was tinted yellow by picric acid and the other blue by methylene blue. When the optimum point of mixing occurred, the individual yellow fibers and the individual blue fibers were indistinguishable macroscopically, and

cross sections under the microscope revealed that they were evenly distributed. The cross sections were made by the use of the device and technique previously mentioned.

Three similar blends of wool tops were also made by the small sample card, and fineness was analyzed in the same manner as in hand-carded blends.

Whole Fleeces

The wool from the fleeces of nine Rambouillet wethers at the Beltsville Research Center was used for the fineness studies in the second part of the experiment. The mean fiber diameter of wool from each fleece was studied by six methods (table 1), the first three of which involved carding, and the last three, methods of cross-sectioning undisturbed samples of wool for fineness.

In methods 3 and 5, the 3 areas sampled—shoulder, side, and hip—are represented in figure 1 by areas 2, 6, and 10, respectively. In method 4, the 12 areas sampled are represented by all those shown in the figure. Method 5 involved the same 3 locks as method 3 except that the cross sections were made before the wool had been carded.

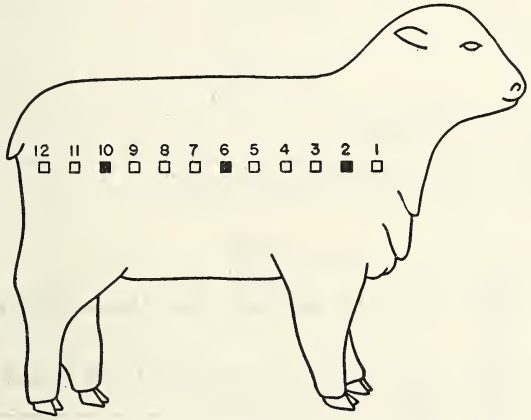

Figure 1.—Areas sampled on a fleece in methods 3, 4, and 5. Areas 2, 6, and 10—at the shoulder, side, and hip, respectively—were sampled in methods 3 and 5; all the areas, in method 4.

Table 1.—*Methods used in determining the fineness of 9 Rambouillet fleeces*

Method No.	Method of mixing	Number of samples and portion of fleece sampled	Weight of each sample	Method of selection or cross sectioning	Observations on each sample
			Grams		*Number*
1	Machine carding	1 sample from right half	125	Random selection from blended sample.	10
2A	Hand carding	do	[1] 3–4	do	8
2B	do	1 sample from left half	3–4	do	8
3	do	1 sample each from shoulder, side, and hip.	0.1	do	6
4	None	12 samples from right side extending from shoulder to hip.	.1	Cross sectioning at middle of staple.	1
5	do	Same as method 3[2]	.1	Cross sectioning at base, middle, and tip of staple.	1
6	do	5 samples from right half	.1	Selection on basis of fineness differences and cross sectioning at middle of staple.	1

[1] Taken before carding from 125-gm. sample used in method 1.
[2] Cross sectionings made before wool was carded.

EXPERIMENTAL RESULTS

Wool Tops

Table 2 gives the results on 11 hand-carded blends made by combining equal weights of two grades of wool tops. The mean diameter of each blend is compared statistically with a weighted arithmetical mean diameter as the simple arithmetical average of the 2 diameters would give a value biased in favor of the coarser wool since there were more fibers of finer wool in each blend. In making the quantitative analysis of component fibers in a blend, although several methods of averaging would give similar results, the method adopted followed the general plan outlined by Von Bergen and Mauersberger (*6*). By this method, the relative number of fibers in each component equals the weight of the component divided by its diameter. If x equals the diameter of one component and y equals the diameter of the second, in a mixture of equal weights of the two, the fractional numbers of fibers in x and y components are as follows:

$$Fx=\frac{y}{x+y} \tag{1}$$

$$Fy=\frac{x}{x+y} \tag{2}$$

The diameter of the blend

$$D_{xy}=\frac{y}{x+y}x+\frac{x}{x+y}y \tag{3}$$

or

$$D_{xy}=\frac{2xy}{x+y} \tag{4}$$

Equation 4 was used to calculate the theoretical diameters of each blend.

TABLE 2.—*Comparison of diameters of hand-carded blends of wool tops with their theoretical diameters*

Grades of wool in blend [1]	Mean diameter of—		Theoretical diameter of blend [2]	Difference between diameter of hand-carded blend and theoretical diameter
	Machine-carded blend	Hand-carded blend		
	Microns	*Microns*	*Microns*	*Microns*
80's and 64's	19.16	19.32	19.25	+0.07
80's and 60's		19.95	19.70	+.25
80's and 56's		21.77	21.99	−.22
80's and 50's		21.70	22.07	−.37
64's and 60's		20.90	20.84	+.06
64's and 58's		22.88	22.80	+.08
64's and 56's		23.80	23.42	+.38
60's and 58's		23.78	23.43	+.35
60's and 56's	24.25	24.65	24.09	+.56
58's and 56's		26.38	26.76	−.38
58's and 50's	26.95	27.20	26.87	+.33
Mean		22.94	22.84	.28
Average positive deviation				+.26
Average negative deviation				−.32
Correlation coefficient r			.9922	
Regression coefficient b_{yx}			.9959	

[1] Grades in each blend are of equal weight.
[2] Calculated from formula 4.

As shown by the table, the greatest difference between the diameter of any hand-carded blend and the theoretical diameter is +0.56 micron and the smallest difference is +0.06 micron. Both the correlation coefficient and regression coefficient approach the theoretical value of unity. Therefore, very intimate mixing is possible by the hand carding of small quantities of wool tops.

The diameters of three blends of machine-carded wool tops are also given in table 2. As this number is small, no statistical comparison was made, but a study of the results shows that they agree closely with the theoretical and also the hand-carded values.

Wool Fleeces

In table 3 the results on carded blends of wool fleeces (methods 1, 2, and 3) are compared with three other methods of sampling fleeces for fineness (methods 4, 5, and 6). Although on the whole differences among the methods are small, unmixed samples appear to be biased. In methods 4 and 5 mean diameters are biased in favor of the small fibers. As a result of selecting samples varying in fineness (method 6) mean diameters are biased in favor of the coarser fibers. This may be attributed to the fact that the coarser portions are more easily recognized by the judge and therefore the composite contains a preponderance of the larger fibers.

Except with method 4, the fibers of fleeces 6 and 7 have the largest diameters and those of fleece 5 have the smallest diameter. The correlation coefficients obtained by comparing the individual methods with method 1 all exceed 0.99 except for method 4, which gives a correlation of 0.988.

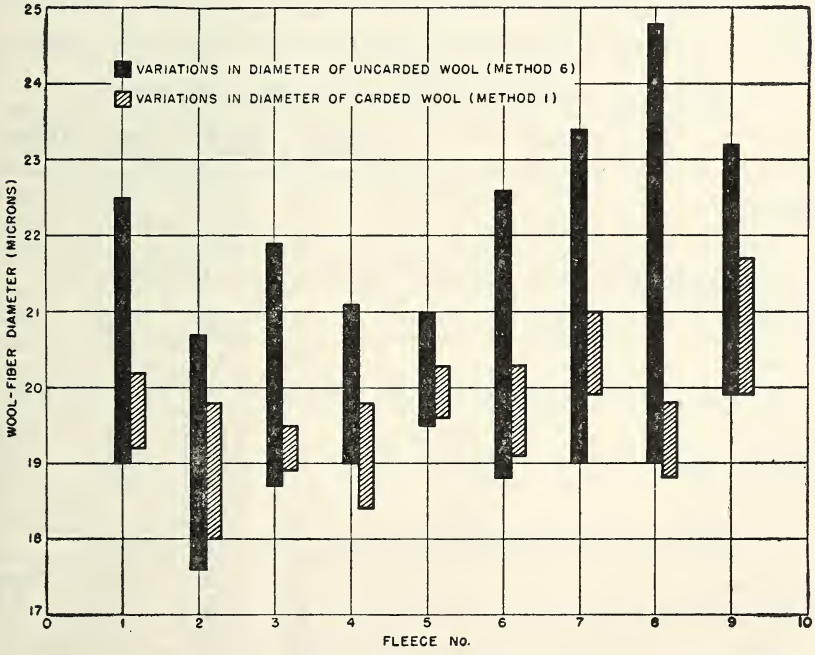

Figure 2.—Range in mean fiber diameters in unblended and carded Rambouillet wool fleeces as obtained in methods 6 and 1, respectively.

Table 4 shows highly significant differences between the mean diameter of wool of different sheep with all methods except method 6, the difference in this case being significant. The analysis of variance in method 5 shows that significant differences occur not only between sheep, but also between body areas on the sheep and between positions along the staple, the last being highly significant. In this case the differences along the staple were greater than sheep and area differences. In view of these findings the importance of shifting the fiber alignment to bring the fibers into the cross-section study is seen.

Graphically the effect of blending by carding is shown in figure 2, in which the maximum variations of mean fiber diameters within a fleece, as obtained with method 6, are compared with variations within a machine-carded blend, as obtained with method 1. In every case, the large variation of mean fiber diameter within a fleece has been reduced by machine carding. A range of 5.8 microns was found in mean wool-fiber diameters of a fleece, which on machine carding was reduced to 1 micron.

TABLE 3.—*Mean diameters of wool fibers from 9 Rambouillet fleeces as determined by different methods*

Method No.	Mean diameter of fleece No.—									
	1	2	3	4	5	6	7	8	9	Average
	Microns	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*
1	19.34	18.90	19.52	19.50	18.51	20.81	20.36	19.57	19.61	19.57
2A	19.44	19.86	19.56	19.14	18.90	20.38	20.58	19.16	19.64	19.63
2B	19.91	19.27	19.29	19.61	18.50	20.61	20.66	19.36	19.53	19.64
3	19.17	18.98	19.29	19.82	18.29	20.02	20.32	18.60	18.96	19.27
4	18.54	19.01	19.08	17.90	17.21	18.90	18.24	16.93	16.98	18.09
5	18.56	18.59	19.02	19.34	17.46	19.58	19.62	17.49	17.56	18.58
6	21.84	20.56	19.92	20.18	18.70	20.86	22.24	20.17	20.00	20.50

TABLE 4.—*Analysis of variance for 6 methods of determining mean diameter of fleeces*

METHOD 1.—MACHINE CARDING SAMPLE FROM HALF FLEECE

Source of variation	Degrees of freedom	Sum of squares	Mean square	Variance ratio [1]
Between sheep	8	37.961	4.745	**13.48
Within sheep	81	28.472	.352	
Total	89	66.433		

METHOD 2A.—HAND CARDING SAMPLE FROM HALF FLEECE

Between sheep	8	31.1120	3.8890	**22.56
Within sheep	63	10.8625	.1724	
Total	71	41.9745		

METHOD 3.—HAND CARDING OF LOCKS FROM SHOULDER, SIDE, AND HIP

Between sheep	8	63.565	7.946	**12.82
Body areas	2	7.646	3.838	**6.16
Sheep × body areas	16	24.380	1.524	**2.46
Remainder	135	83.722	.620	
Total	161	179.313		

METHOD 4.—CROSS SECTIONING SAMPLES FROM 12 BODY AREAS

Between sheep	8	75.545	9.4430	**18.58
Body areas	11	5.546	.5042	1.01
Sheep × body areas	88	44.711	.5081	
Total	107	125.802		

[1] See table 1 for description of method.

TABLE 4.—*Analysis of variance for 6 methods of determining mean diameter of fleeces*—Continued

METHOD 5.—CROSS SECTIONING SAMPLES FROM SHOULDER, SIDE, AND HIP AT BASE, MIDDLE, AND TIP OF FIBERS

Source of variation	Degrees of freedom	Sum of squares	Mean square	Variance ratio [1]
Between sheep	8	46.7440	5.8430	**5.66
Body areas	2	9.6357	4.8179	*4.67
Positions along staple	2	67.0108	33.5054	**32.45
Remainder	68	70.2043	1.0324	
Total	80	193.5948		

METHOD 6.—CROSS SECTIONING 5 SAMPLES SELECTED FOR DIFFERENCES IN FINENESS

Between sheep	8	42.556	5.320	*2.90
Within sheep	36	66.036	1.834	
Total	44	108.592		

[1] *=Significant difference, as determined by the method of Snedecor (*5*); **=highly significant difference.

A comparison of the accuracy of the six methods is given in table 5. The standard deviations are derived from the best estimate of the error, which is the within-sheep variation for methods 1, 2, and 6; the first-order interaction, sheep × body areas, for methods 3 and 4; and the remainder for method 5. In table 5, in order to analyze the methods on a comparable basis, the standard error and difference required to show a significant difference between sheep were calculated, 10 observations being assumed for each method. Methods 1 and 2 show considerably less error and therefore more precision than remaining methods. For example, by cross-sectioning one carded sample drawn from a whole fleece, a difference of less than 0.8 micron can be shown to be highly significant. Only by taking 12 samples, as in method 4, does the ordinary procedure of cross-sectioning unmixed samples approach the accuracies found in methods 1 and 2. However, machine carding has a considerable advantage over hand carding because the machine will handle larger samples. Hand carding of the samples from the shoulder, side, and hip gave a standard error of 0.249 micron compared with 0.321 micron where 3 positions are cross-sectioned along the staple. Method 6 illustrates the large potential variation that occurs within a fleece of fine wool.

TABLE 5.—*Comparison of the accuracy of the 6 methods*

Method No. [1]	Standard deviation [2]	Standard error of means [3]	Difference required to show a significant difference between means of diameters of fleeces [4] at —	
			5-percent level	1-percent level
	Microns	*Microns*	*Microns*	*Microns*
1	0.593	0.187	0.557	0.763
2	.415	.131	.390	.534
3	.787	.249	.739	1.013
4	.713	.225	.670	.918
5	1.016	.321	.954	1.307
6	1.354	.429	1.272	1.743

[1] See table 1 for description of method.

[2] For method of deriving standard deviation, see text.

[3] Based on 10 observations so that standard error = $\frac{S}{\sqrt{10}}$ (S= standard deviation).

[4] Calculated from $d=ts\sqrt{\frac{2}{N}}$, in which d=difference in microns, t is from Snedecor's (*5, p. 38*) table for t, and N=10, the number of observations taken as constant for each method.

SUMMARY

To determine the reliability of the carding method for obtaining a representative sample of wool to be used in measuring the mean fiber diameter of the fleece, studies were carried on at the United States Department of Agriculture, Beltsville Research Center, Beltsville, Md., in 1941 and 1942. The study involved hand and machine carding.

In tests on mixtures of wool tops, fibers varying greatly in diameter were successfully blended to produce a homogeneous sample by the hand carding of small quantities of wool, as well as by the machine carding of larger samples.

Tests on nine Rambouillet fleeces gave results that would otherwise be possible only by an elaborate zoning procedure. In this phase of the study, six methods of obtaining fiber diameter were used—one involving machine carding; two, hand carding; and three, the usual methods of sampling fleeces for fineness. This phase of the study showed large differences between wool fibers of various fleeces, various body areas, and along the length of the staple, the last being highly significant. By either hand or machine carding the fiber variation along the staple and from different regions of the fleece may be brought into cross-section view for analysis.

The effect of blending by carding is strikingly illustrated from the results obtained with method 6 (one of the usual methods of sampling) and method 1 (involving machine carding). The large variation of mean fiber diameter within each of the nine fleeces was reduced by machine carding. In one fleece, the reduction was from 5.8 microns to 1 micron.

The machine-carding method and one of the hand-carding methods were found to be more precise than any of the others. However, machine carding has a considerable advantage over hand carding because the machine will handle larger samples.

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